

Prepared in cooperation with the Idaho Department of Water Resources

Water Budgets for Coeur d'Alene Lake, Idaho, Water Years 2000–2005



Scientific Investigations Report 2009–5184

Cover: Photographs showing various views of development along the shores of Coeur d'Alene Lake, Idaho. (Photograph courtesy U.S. Geological Survey, Idaho Water Science Center)

Water Budgets for Coeur d'Alene Lake, Idaho, Water Years 2000–2005

By Molly A. Maupin and Rhonda J. Weakland

Prepared in cooperation with the Idaho Department of Water Resources

Scientific Investigations Report 2009-5184

**U.S. Department of the Interior
U.S. Geological Survey**

U.S. Department of the Interior

KEN SALAZAR, Secretary

U.S. Geological Survey

Suzette M. Kimball, Acting Director

U.S. Geological Survey, Reston, Virginia: 2009

For more information on the USGS—the Federal source for science about the Earth, its natural and living resources, natural hazards, and the environment, visit <http://www.usgs.gov> or call 1-888-ASK-USGS

For an overview of USGS information products, including maps, imagery, and publications, visit <http://www.usgs.gov/pubprod>

To order this and other USGS information products, visit <http://store.usgs.gov>

Any use of trade, product, or firm names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

Although this report is in the public domain, permission must be secured from the individual copyright owners to reproduce any copyrighted materials contained within this report.

Suggested citation:

Maupin, M.A., and Weakland, R.J., 2009, Water budgets for Coeur d'Alene Lake, Idaho, water years 2000–2005: U.S. Geological Survey Scientific Investigations Report 2009-5184, 16 p.

Contents

Abstract	1
Introduction.....	1
Purpose and Scope	1
Description of Study Area	1
Water Budgets for Coeur d’Alene Lake, Water Years 2000–2005	4
Data Used in This Study.....	6
Inflows	7
Outflows.....	9
Precipitation and Evaporation	9
Lake Storage and Withdrawals	11
Uncertainties of Water Budget Components	13
Summary and Conclusions.....	14
References Cited.....	15

Figures

Figure 1. Map showing locations of National Weather Service stations and U.S. Geological Survey pelagic monitoring stations in and near Coeur d’Alene Lake, northern Idaho	2
Figure 2. Graph showing changes in population for the cities of Harrison, Plummer, St. Maries, and Coeur d’Alene, Idaho, from 1980 to 2006	3
Figure 3. Schematic diagram showing water budget for Coeur d’Alene Lake, Idaho	4
Figure 4. Graph showing annual surface-water inflows and outflows, precipitation, evaporation, consumptive use, and surface-water losses to the Spokane Valley-Rathdrum Prairie aquifer, water years 2000–2005	5

Tables

Table 1. Water budgets and mean annual water budget, Coeur d'Alene Lake, Idaho, water years 2000–2005	6
Table 2. Locations, drainage area, and period of record for U.S. Geological Survey stream-gaging and pelagic monitoring stations, National Weather Service stations, and the city of Coeur d'Alene wastewater treatment facility in the Coeur d'Alene Lake drainage basin, northern Idaho	7
Table 3. Annual surface-water inflow and outflow at gaged and ungaged tributaries of Coeur d'Alene Lake, Idaho, water years 2000–2005	8
Table 4. Summary of mean monthly air temperature, dew point, wind speed, and precipitation data from National Weather Service stations, mean monthly water temperature from U.S. Geological Survey pelagic monitoring stations, 1991–2006, and calculated mean monthly and total mean annual precipitation to and evaporation from Coeur d'Alene Lake, Idaho	10
Table 5. Change in storage and summary of mean monthly storage, Coeur d'Alene Lake, Idaho, water years 2000–2005	12
Table 6. Summary of monthly estimated surface-water withdrawals, and consumptive use, for domestic and municipal water uses, Coeur d'Alene Lake, Idaho	13

Conversion Factors, Datums, and Abbreviations and Acronyms

Conversion Factors

Inch/Pound to SI

Multiply	By	To obtain
Length		
inch (in.)	2.54	centimeter (cm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
Area		
acre	4,047	square meter (m ²)
square mile (mi ²)	2.590	square kilometer (km ²)
Volume		
cubic foot (ft ³)	0.02832	cubic meter (m ³)
acre-foot (acre-ft)	1,233	cubic meter (m ³)
Flow rate		
acre-foot per year (acre-ft/yr)	1,233	cubic meter per year (m ³ /yr)
cubic foot per second (ft ³ /s)	0.02832	cubic meter per second (m ³ /s)
cubic foot per year (ft ³ /yr)	0.02832	cubic meter per year (m ³ /yr)
gallon per day (gal/d)	0.003785	cubic meter per day (m ³ /d)
inch per month (in/month)	30.48	centimeter per year (cm/yr)
Pressure		
atmosphere, standard (atm)	101.3	kilopascal (kPa)

Conversion Factors, Datums, and Abbreviations and Acronyms—Continued

SI to Inch/Pound

Multiply	By	To obtain
Length		
meter (m)	3.281	foot (ft)
Flow rate		
meter per second (m/s)	3.281	foot per second (ft/s)
millimeter per day (mm/d)	0.03937	inch per day (in/d)
Density		
kilogram per cubic meter (kg/m ³)	0.06242	pound per cubic foot (lb/ft ³)
Energy		
megajoules per kilogram (MJ/kg)	0.126	kilowatt-hours per pound (kWh/lb)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

$$^{\circ}\text{F}=(1.8\times^{\circ}\text{C})+32.$$

Datums

Vertical coordinate information is referenced to the North American Datum of 1988 (NAVD 88).

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Abbreviations and Acronyms

GPCD	gallon per capita per day
IDWR	Idaho Department of Water Resources
NWS	National Weather Service
SVRP	Spokane Valley-Rathdrum Prairie
USGS	U.S. Geological Survey
WWTF	wastewater treatment facility

This page intentionally left blank.

Water Budgets for Coeur d'Alene Lake, Idaho, Water Years 2000–2005

By Molly A. Maupin and Rhonda J. Weakland

Abstract

The U.S. Geological Survey, in cooperation with the Idaho Department of Water Resources, calculated annual water budgets and a mean annual water budget for Coeur d'Alene Lake, Idaho, for water years 2000 through 2005. Mean annual inflow to Coeur d'Alene Lake, including precipitation, was about 167,110 million cubic feet. Mean annual outflow, including evaporation, but excluding wastewater effluent to the Spokane River, was about 167,850 million cubic feet. The amount of water lost from Coeur d'Alene Lake and the Spokane River to the Spokane Valley-Rathdrum Prairie aquifer was estimated at 7,250 million cubic feet. Mean annual precipitation into Coeur d'Alene Lake was 3,267 million cubic feet, which exceeded mean annual evaporation of 2,483 million cubic feet. Withdrawals directly from the lake and from wells within a 1,000 foot buffer of the lakeshore for domestic and municipal water uses were reported. However, only the estimate for the consumptive use part of the withdrawals, 265 million cubic feet, was considered in the budget. Mean annual change in lake storage resulted in a net loss of about 49 million cubic feet. The mean annual residual value was about -8,310 million cubic feet.

Introduction

The shoreline of Coeur d'Alene Lake in northern Idaho has been developed for residential and commercial land uses. In addition, communities bordering the lake have experienced rapid population growth. Water managers and private landowners are concerned about the effects of rapid growth and increasing water demands from the lake on the available surface-water supplies. Of particular concern is the possibility of declining lake levels because of new residential and commercial developments. An updated surface-water budget for Coeur d'Alene Lake is needed to help resource managers determine how growth and rising water demands will affect lake water levels. Most previous studies of Coeur d'Alene Lake focused on water-quality issues in relation to nutrient loads and trace element enrichment from contributing drainage basins, primarily the mining districts in the Coeur d'Alene River basin (Wood and Beckwith, 2008). The last water budget for Coeur d'Alene Lake was calculated for water years 1991 and 1992 (Woods and Beckwith, 1997).

In 2007, the U.S. Geological Survey (USGS) began a cooperative project with the Idaho Department of Water Resources (IDWR) to develop annual surface-water budgets and a mean annual surface-water budget for Coeur d'Alene Lake for water years 2000 through 2005. A water year is defined as a year beginning October 1 and ending September 30 of the following year—thus, water year 2000 begins on October 1, 1999, and ends on September 30, 2000. A water budget helps resource managers to quantify the components of a surface-water budget for a lake and to identify any adverse effects that rapid growth may have on the water levels of a lake. A decline or rise in the water level of the lake is indicated by a respective negative or positive net change in the lake storage term of the water budget.

Purpose and Scope

This report presents the annual water budgets and summarizes the components used to develop water budgets for Coeur d'Alene Lake for water years 2000–2005. The components of the water budget considered in this study are surface-water inflow and outflow, precipitation, evaporation, change in lake storage, estimate of consumptive use (for withdrawals from the lake for domestic and municipal uses and from wells close to the lakeshore), streamflow loss to the Spokane Valley-Rathdrum Prairie aquifer from the Spokane River between the outlet of Coeur d'Alene Lake and Post Falls Dam, seepage loss from Coeur d'Alene Lake to the aquifer, a residual value that includes error in estimates and measured data, and unmeasured components of the water budget. For example, calculations of groundwater fluxes between the lake and groundwater systems around the lake, or evapotranspiration from vegetation around the lake, which are both part of a water budget were not quantified in this study and are included in the residual value.

Description of Study Area

Coeur d'Alene Lake is in northern Idaho within the 6,680 mi² Spokane River basin ([fig. 1](#)). The lake is the second largest in the State, with a drainage area of about 3,740 mi² (2.4 million acres). The lake is bordered by forested mountains to the east and a combination of forest and cultivated land

2 Water Budgets for Coeur d'Alene Lake, Idaho, Water Years 2000-2005

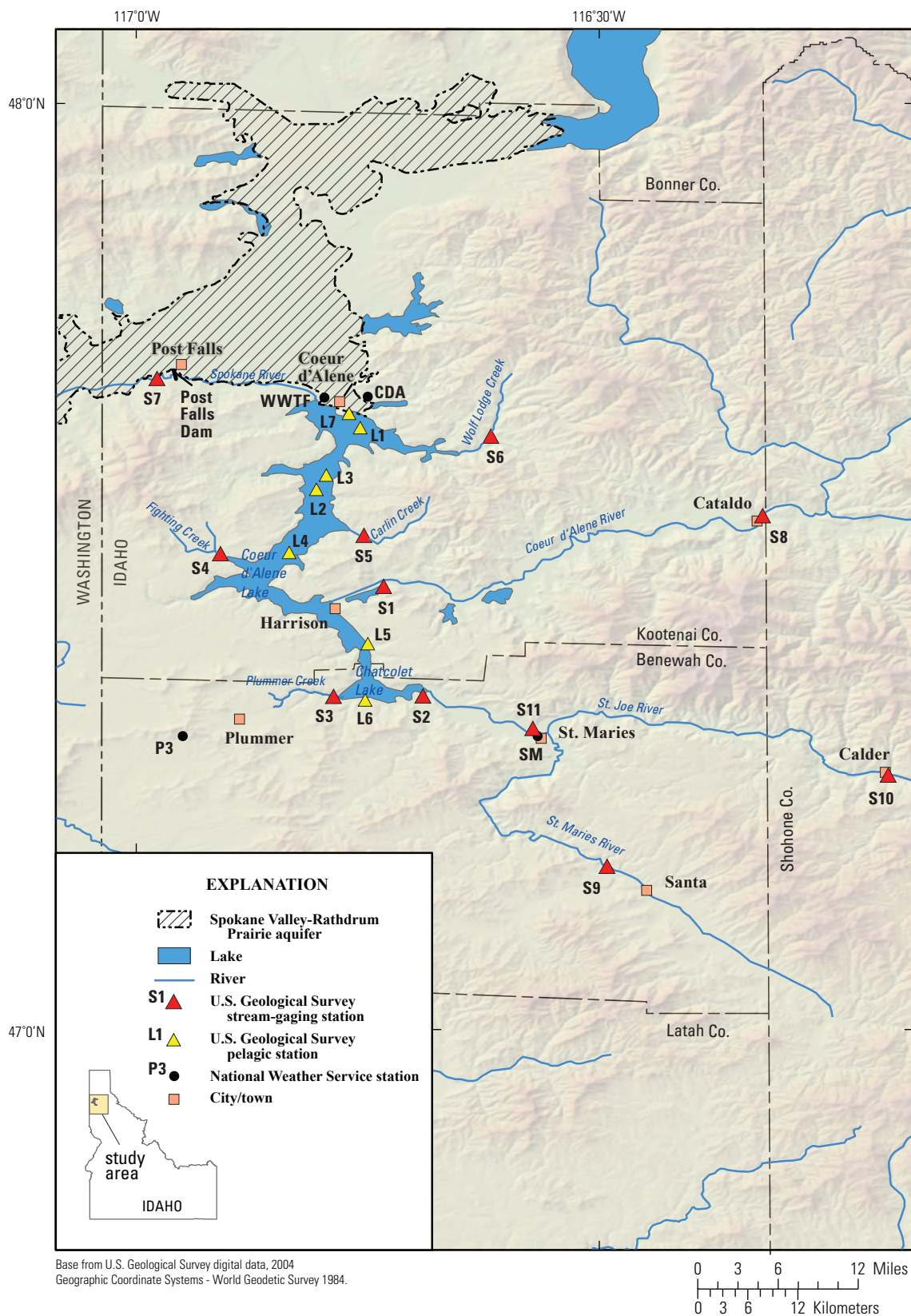


Figure 1. Locations of National Weather Service stations and U.S. Geological Survey pelagic monitoring stations in and near Coeur d'Alene Lake, northern Idaho.

to the west. Most population, recreational use of the lake, and lakeshore development are in Kootenai County (Woods and Beckwith, 1997). Most surface-water inflows to the lake are from two large rivers, the Coeur d'Alene and the St. Joe, which enter the lake from the east and southeast, respectively (fig. 1). Smaller tributaries to the lake include Wolf Lodge Creek, Carlin Creek, Plummer Creek, and Fighting Creek. The city of Coeur d'Alene borders the northern shore of the lake and the smaller communities of St. Maries, Harrison, and Plummer are to the south, east, and west, respectively. The lake is almost completely surrounded by campgrounds, marinas, and hundreds of single-family homes, many of which are summer homes occupied seasonally.

At a full summer pool elevation of 2,132 ft (NAVD 88), Coeur d'Alene Lake covers about 50 mi² and has 135 mi of shoreline and a north-south length of about 22 mi. The outlet of the lake is at the northern end near the city of Coeur d'Alene, where water flows into the Spokane River. Lake levels are regulated by Post Falls Dam, about 11 mi downstream on the Spokane River near Post Falls, Idaho. The southern end of the lake is under the jurisdiction of the Coeur d'Alene Tribe. The southernmost areas of the lake are shallow because prior to the construction of Post Falls Dam in 1906 the area was primarily emergent wetlands.

Most population in the study area is concentrated in the four communities of Coeur d'Alene, Harrison, St. Maries, and Plummer. In 2006, the estimated total population of these communities was 45,000 (U.S. Census Bureau, 2008; fig. 2). The city of Coeur d'Alene is the largest of the four communities, with approximately 41,000 residents in an area of about 14 mi². The combined total population of St. Maries, Plummer, and Harrison was 3,980 people in 2006, less than 10 percent of the population of Coeur d'Alene. From 1980 to 2006, the total population in communities surrounding the lake increased 88 percent.

The climate of the Coeur d'Alene Lake drainage area is mild and arid during summer, and is cold and wet during winter. Approximately 70 percent of the total annual precipitation falls between October and April, and about one-half of that precipitation falls as snow. The driest months are July and August. Mean annual precipitation ranges from 20 in. near the lake to 50–60 in. in the higher elevations of the drainage basin (Molnau, 2000). Rain-on-snow events are not uncommon during winter; heavy runoff occurs in April and May, but can continue into June. Precipitation-bearing storms usually originate from the northwest over the Pacific Ocean, but occasionally storms will originate from the north over Canada. Mean monthly temperatures (based on long-term records at all three weather stations) range from -1.6 to 20°C the coolest monthly averages occur in January and the warmest averages occur in July. Mean summer temperatures are about 16°C, and mean winter temperatures are about -1.1°C (Western Regional Climate Center, 2008).

After a near-normal start in water year 2000, northern Idaho experienced a cycle of wet and dry years between 2001 and 2005. The following percentages are for average precipitation and streamflow conditions as compared to 30-year averages for major drainage basins in northern Idaho (Panhandle). Water year 2000 was a near-normal year with 102 percent of average precipitation and 104 percent of average streamflow. However, water year 2001 was the driest year during the study period, with 59 percent of average precipitation and only 42 percent of average streamflow. The cycle turned wet in water year 2002 and was the wettest year in the study period with 110 percent of average precipitation and 125 percent of average streamflow. Drier conditions returned during water year 2003 with 84 percent of average precipitation and 75 percent of average streamflow. Water year 2004 had mixed conditions with above-average precipitation (104 percent), but below-average streamflow (74 percent). Water year 2005 had below-average precipitation (82 percent) and streamflow (76 percent).

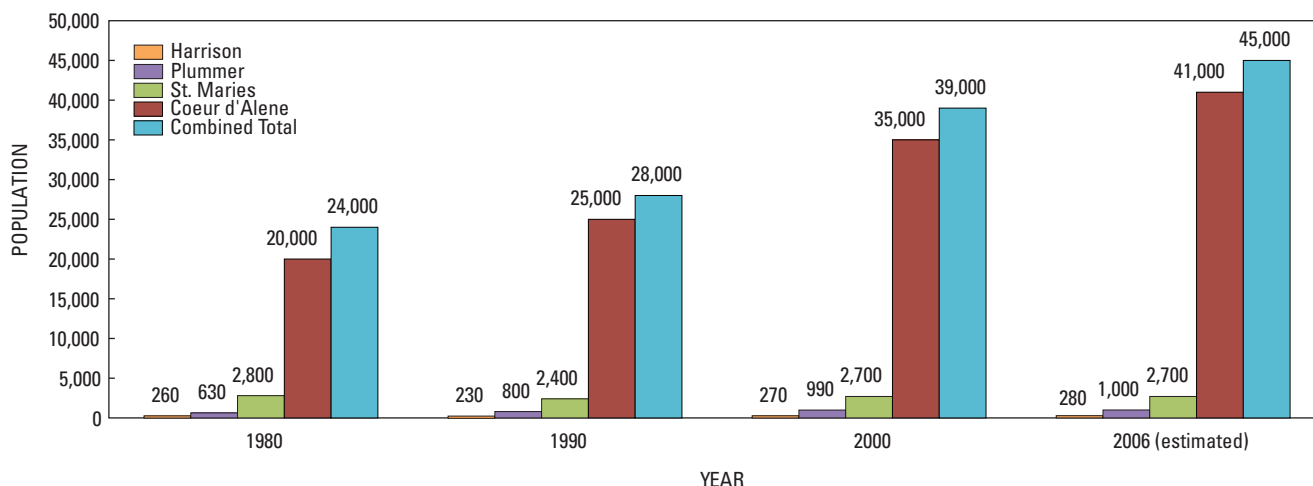


Figure 2. Changes in population for the cities of Harrison, Plummer, St. Maries, and Coeur d'Alene, Idaho, from 1980 to 2006. Source data are from the U.S. Census Bureau, 2008.

Water Budgets for Coeur d'Alene Lake, Water Years 2000–2005

The Coeur d'Alene Lake water budget accounts for surface-water inflows, precipitation to the lake surface, surface-water outflows, evaporation from the lake surface, losses from the Coeur d'Alene Lake and Spokane River to the Spokane Valley-Rathdrum Prairie (SVRP) aquifer, lake storage change, consumptive use from domestic and municipal withdrawals, and a residual value. This water budget is expressed in equation 1 and illustrated in [figure 3](#).

$$R = SWGin + SWUin + P - SWout - E - GW - \Delta S - CU, \quad (1)$$

where

R is the residual value,

$SWGin$ is surface-water inflow from gaged tributaries,

$SWUin$ is surface-water inflow from ungaged tributaries,

P is precipitation onto the lake surface,

$SWout$ is surface-water outflow at Spokane River near Post Falls station, adjusted for effluent flows into the Spokane River from the Coeur d'Alene wastewater treatment facility (WWTF),

E is lake water-surface evaporation,

GW is surface-water losses to the SVRP aquifer,

ΔS is net change in storage, either a gain (positive) or loss (negative), and

CU is consumptive-use losses from withdrawals for domestic and municipal uses.

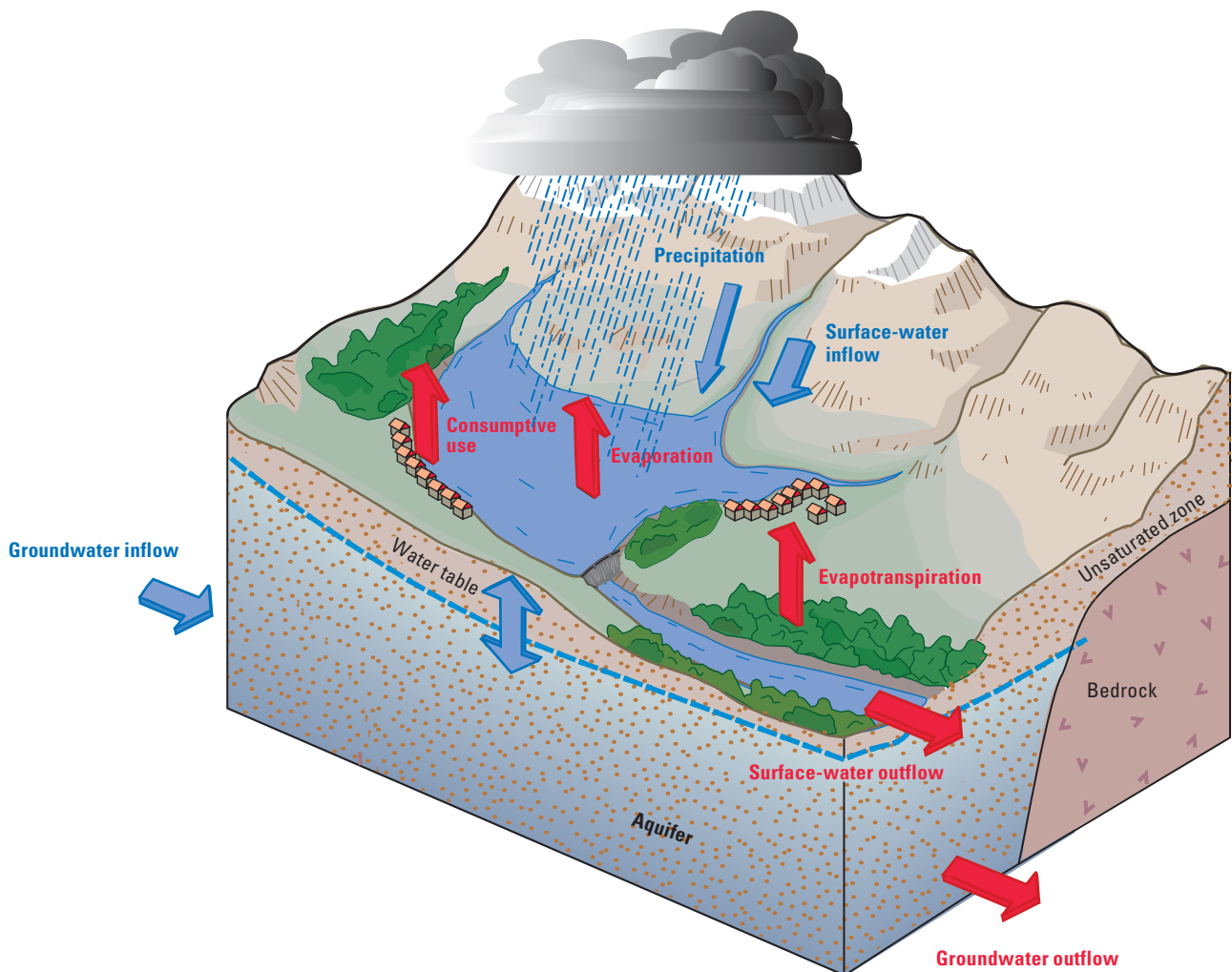


Figure 3. Water budget for Coeur d'Alene Lake, Idaho.

Annual budgets for water years 2000–2005 are reported in [figure 4](#) and [table 1](#). The largest gain to the water budgets is from the surface-water inflows from the six gaged tributaries, making up most of the total mean annual inflow. The largest loss to the water budgets is the outflow to the Spokane River, which serves as the natural outlet of the lake.

Mean annual inflow to Coeur d'Alene Lake for the study period, including precipitation, was about 167,110 million ft³ (3,836 thousand acre-ft). Mean annual outflow, using Spokane River flows adjusted for Coeur d'Alene wastewater treatment facility effluent, and including evaporation, was about 167,850 million ft³ (3,853 thousand acre-ft). Losses from Coeur d'Alene Lake and the Spokane River to the SVRP aquifer were 7,250 million ft³ (167,000 acre-ft). Mean annual precipitation into Coeur d'Alene Lake was 3,267 million ft³ (75,000 acre-ft), which exceeded mean annual evaporation of 2,483 million ft³ (57,000 acre-ft). Consumptive use for surface-water and groundwater withdrawals was 265 million ft³ (6,100 acre-ft). Mean annual change in storage resulted in a net loss of about 49 million ft³ (1,100 acre-ft). The residual value was about -8,310 million ft³ (191,000 acre-ft).

Inflows to Coeur d'Alene Lake from the two largest tributaries, Coeur d'Alene and St. Joe Rivers, account for almost 1.5 times the total volume of the lake, about 100,300 million ft³ (2.3 million acre-ft) (Woods and Beckwith, 1997). During 2000–2005, the two rivers contributed a combined mean annual inflow of about 151,184 million ft³ (3.5 million acre-ft). Inflow from gaged tributaries was 92 percent of the mean annual total inflows, and ungaged inflows 6 percent of the total mean annual inflows. Mean annual precipitation was about 2 percent of the total inflows. The Spokane River carried 94 percent of the mean annual total outflows, and evaporation was about 1.5 percent of the mean annual total outflows. Estimates for the losses to the SVRP aquifer from Coeur d'Alene Lake and the Spokane River were 4 percent of the total mean annual outflows. Consumptive use was 0.2 percent of the total mean annual outflows. Net change in storage was 0.03 percent of the total mean annual outflows. The mean annual residual value was 5 percent of the total inflows and nearly 5 percent of the total outflows. Each water year has a negative residual value, but the residual values are within an acceptable margin of error for the budget components that are the largest percentage of total inflows and outflows.

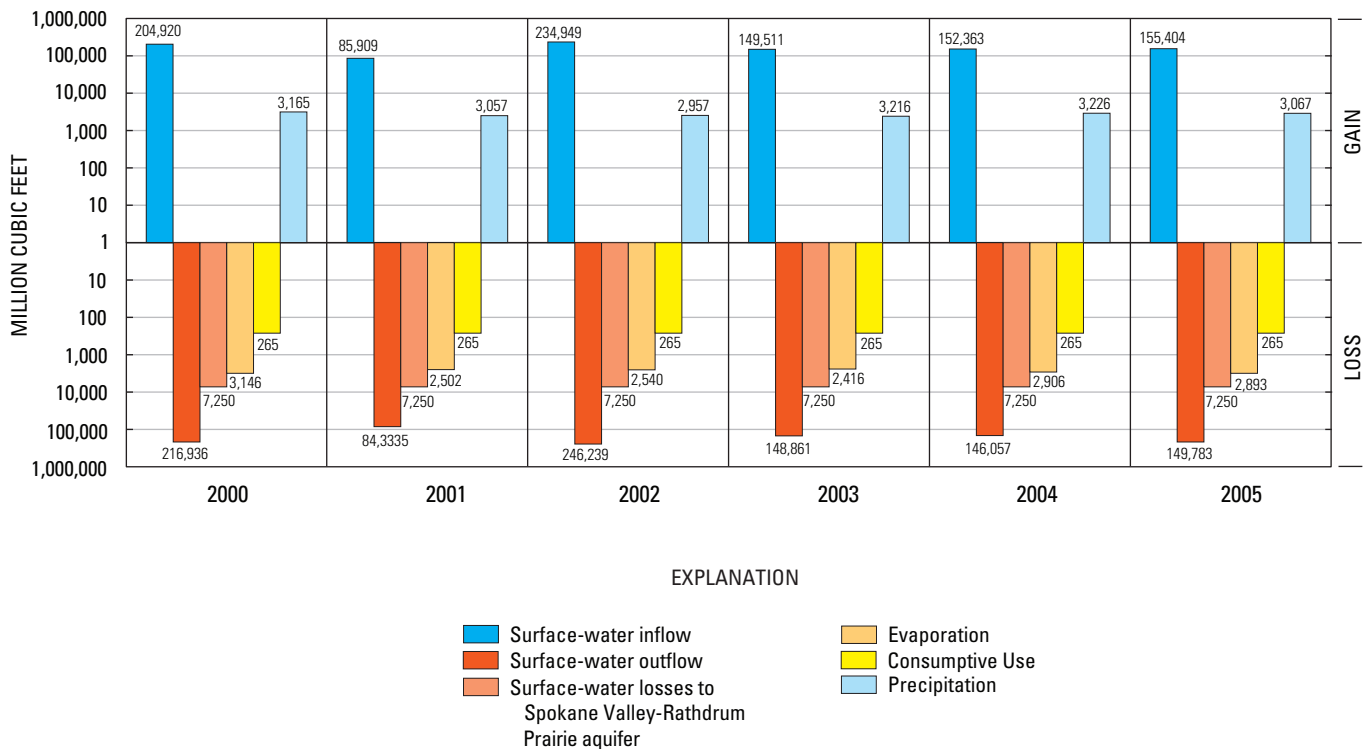


Figure 4. Annual surface-water inflows and outflows, precipitation, evaporation, consumptive use, and surface-water losses to the Spokane Valley-Rathdrum Prairie aquifer, water years 2000–2005.

6 Water Budgets for Coeur d'Alene Lake, Idaho, Water Years 2000-2005

Table 1. Water budgets and mean annual water budget, Coeur d'Alene Lake, Idaho, water years 2000–2005.

[Locations of sites shown in [figure 1](#). Numbers in parentheses are station numbers listed in [table 2](#). Abbreviations: mi², square mile; in., inch]

Tributary or budget component	Site No.	Station No.	Drainage area (mi ²)	Yield (in.)	Water budget						
					Water year						Mean annual, 2000–2005
					2000	2001	2002	2003	2004	2005	
Inflow (million cubic feet)											
Coeur d’Alene River near Harrison	S1	12413860	1,475	20	86,671	33,281	104,170	57,919	61,439	67,520	68,500
St. Joe River near Chatcolet	S2	12415140	1,720	20.7	104,897	41,208	116,893	79,166	78,522	75,418	82,684
Plummer Creek near Plummer	S3	12415250	43.4	7	900	354	1,003	679	640	647	704
Fighting Creek near Rockford Bay	S4	12415285	15.0	9.6	428	168	477	323	305	308	335
Carlin Creek near Harrison	S5	12415290	10.8	10	319	122	385	214	220	229	248
Wolf Lodge Creek near Coeur d’Alene	S6	12415350	39.4	12.8	1,508	579	1,823	1,013	1,040	1,085	1,175
Precipitation					3,165	3,057	2,957	3,216	3,226	3,067	3,267
Unengaged tributaries			447	9.8	10,197	10,197	10,197	10,197	10,197	10,197	10,197
Outflow (million cubic feet)											
Spokane River near Post Falls (adjusted for effluent)	S7	12419000	3,840	21.9	216,936	84,335	246,239	148,861	146,057	149,783	165,369
Evaporation					3,146	2,502	2,540	2,416	2,906	2,893	2,483
Consumptive water use (surface-water and groundwater uses)					265	265	265	265	265	265	265
Storage change (Coeur d’Alene Lake at Coeur d’Alene) (negative means a net gain, positive means net loss)	L7	12415500			-251	231	0	113	-688	891	49
Surface-water losses from Spokane River between outlet and Post Falls Dam at Post Falls (Wyman, 1993), and seepage from Couer d’Alene Lake to Spokane Valley-Rathdrum Prairie aquifer					7,250	7,250	7,250	7,250	7,250	7,250	7,250
Total inflows					208,085	88,966	237,905	152,727	155,589	158,471	167,110
Total outflows					227,346	94,583	256,294	158,905	155,790	161,082	175,416
Residual (inflows-outflows)					-19,261	-5,617	-18,389	-6,178	-201	-2,611	-8,306
Residual as percentage of inflows					9.3	6.3	7.7	4.0	0.1	1.6	4.9
Residual as percentage of outflows					8.5	5.9	7.2	3.9	0.1	1.6	4.7

Data Used in This Study

Components of the water-budget include surface-water inflow and outflow, precipitation and evaporation, changes in lake storage, and estimates of consumptive use for withdrawals from the lake for domestic and municipal uses and from wells near the lakeshore. Referenced values of streamflow losses to the SVRP aquifer from the Spokane River between the outlet of Coeur d'Alene Lake and Post Falls Dam, seepage from Coeur d'Alene Lake to the SVRP aquifer, and a residual value also are considered in the budget and explained in this section.

Surface-water inflow was calculated using six USGS stream-gaging stations (S1, S2, S3, S4, S5, S6) on tributaries to Coeur d'Alene Lake. Surface-water outflow was computed using one stream-gaging station (S10) on the Spokane

River about 11 mi downstream of the lake outlet ([fig. 1](#)). Precipitation to the lake was calculated using data collected from three National Weather Service (NWS) weather stations (CDA, P3, SM) on the perimeter of the lake. Evaporation was calculated using wind speed, air temperature, and dew point data collected from the weather stations, and water temperature and wind speed data collected from six USGS pelagic stations (L1, L2, L3, L4, L5, and L6) on the lake ([fig. 1](#), [table 2](#)). These data were combined to estimate evaporation from deep water bodies using methods described by Allen and Robison (2007). Changes in lake storage were calculated using mean monthly stage at the USGS lake station (L7) on Coeur d'Alene Lake. Withdrawals from the lake were estimated using reported withdrawals from purveyors if available, or otherwise from water rights data and domestic water-use coefficients. Consumptive use was estimated as a percentage of the total withdrawals.

Table 2. Locations, drainage area, and period of record for U.S. Geological Survey stream-gaging and pelagic monitoring stations, National Weather Service stations, and the city of Coeur d'Alene wastewater treatment facility in the Coeur d'Alene Lake drainage basin, northern Idaho.

[Locations of sites shown in [figure 1](#). **Abbreviations:** NAD83, North American Datum of 1983; NWS, National Weather Service; USEPA, U.S. Environmental Protection Agency; USGS, U.S. Geological Survey; WWTF, wastewater treatment facility; mi, mile; mi², square mile; na, not applicable]

Agency	Site No.	Station No.	Station name	Decimal latitude (NAD83)	Decimal longitude (NAD83)	Drainage area (mi ²)	Period of record
NWS	CDA	101956	Coeur d'Alene 1E	47.6830	-116.7500	na	1895–current
NWS	P3	107188	Plummer 3 WSW	47.3170	-116.9500	na	1950–current
NWS	SM	108062	St. Maries	47.3170	-116.5670	na	1948–current
USGS	S1	12413860	Coeur d'Alene River near Harrison	47.4786	-116.7331	1,475	2004–current
USGS	S2	12415140	St. Joe River near Chatcolet	47.3603	-116.6906	1,720	2004–current
USGS	S3	12415250	Plummer Creek near Plummer	47.3595	-116.7875	43.4	1991–92
USGS	S4	12415285	Fighting Creek near Rockford Bay	47.5135	-116.9096	15	1991–92
USGS	S5	12415290	Carlin Creek near Harrison	47.5334	-116.7547	10.8	1991–92
USGS	S6	12415350	Wolf Lodge Creek near Coeur d'Alene	47.6408	-116.6173	39.4	1986–94
USGS	S7	12419000	Spokane River near Post Falls	47.7025	-116.9808	¹ 3,840	1913–current
USGS	S8	12413500	Coeur d'Alene River at Cataldo	47.5547	-116.3239	1,223	1986–current
USGS	S9	12414900	St. Maries River near Santa	47.1764	-116.4917	275	1965–current
USGS	S10	12414500	St. Joe River at Calder	47.2747	-116.1881	1,030	1911–current
USGS	S11	12415075	St. Joe River at St. Maries	47.3173	-116.5611	1,682	1973–93
USGS	L1	473900116453000	Coeur d'Alene Lake 1.3 mi southeast of Tubbs Hill near Coeur d'Alene	47.6500	-116.7583	na	1991–2006
USGS	L2	473555116474300	Coeur d'Alene Lake near Driftwood Point near Coeur d'Alene	47.5798	-116.7953	na	2003–05
USGS	L3	473500116482000	Coeur d'Alene Lake 0.8 mi southwest of Driftwood Point near Coeur d'Alene	47.5833	-116.8056	na	1991–2006
USGS	L4	473054116500600	Coeur d'Alene Lake 1.7 mi northeast of University Point near Harrison	47.5150	-116.8350	na	1991–2006
USGS	L5	472500116450000	Coeur d'Alene Lake northeast of Blue Point near Harrison	47.4167	-116.7500	na	1991–2006
USGS	L6	472120116451000	Chatcolet Lake 0.4 mi northwest of Rocky Point near Plummer	47.3556	-116.7528	na	1991–2006
USGS	L7	12415500	Coeur d'Alene Lake at Coeur d'Alene	47.6652	-116.7703	na	1903–current
USEPA	CDA WWTF	ID0022853	City of Coeur d'Alene Wastewater Treatment Facility	47.6823	-116.7971	na	2000–2005

¹ About 122 mi² is noncontributing.

Inflows

Surface-water inflows to Coeur d'Alene Lake were calculated using several methods and data sources because continuous, measured data were not available for all tributaries for water years 2000–2005. All measured data are compliant with USGS data collection techniques and standard protocol (Rantz and others, 1982). Ungaged tributary inflows were calculated using the balance of the drainage area of the basin and average yield calculated from four (S3, S4, S5, S6) of the six gaged tributaries.

Inflows from the two largest drainage basins were calculated using data from USGS stream-gaging stations at Coeur d'Alene River near Harrison (S1) and St. Joe River near Chatcolet (S2) ([table 3](#)). Flows at the Coeur d'Alene River near Harrison stream-gaging station for water years 2000–2003 and part of water year 2004 (October 2003–February 2004) were derived from the FOURPT model of the Coeur d'Alene River (Beckwith and others, 1997). Flows for the remainder of water year 2004 (March 2004–September 2004) and for water year 2005 were measured using an acoustic Doppler velocity meter and stage sensor installed at the site.

8 Water Budgets for Coeur d'Alene Lake, Idaho, Water Years 2000-2005

Table 3. Annual surface-water inflow and outflow at gaged and ungaged tributaries of Coeur d'Alene Lake, Idaho, water years 2000–2005.

[Locations of sites shown in [figure 1](#). **Abbreviations:** USGS, U.S. Geological Survey; WWTF, wastewater treatment facility]

Site No.	Station No.	Station name	Flow, in millions of cubic feet						
			Water year						Mean annual, 2000–2005
			2000	2001	2002	2003	2004	2005	
Inflow									
S1	12413860	Coeur d'Alene River near Harrison	86,671	33,281	104,170	57,919	61,439	67,520	68,500
S2	12415140	St. Joe River near Chatcolet	104,897	41,208	116,893	79,166	78,522	75,418	82,684
S3	12415250	Plummer Creek near Plummer	900	354	1,003	679	640	647	704
S4	12415285	Fighting Creek near Rockford Bay	428	168	477	323	305	308	335
S5	12415290	Carlin Creek near Harrison	319	122	386	214	220	229	248
S6	12415350	Wolf Lodge Creek near Coeur d'Alene	1,508	579	1,823	1,013	1,040	1,085	1,175
		Ungaged tributary inflow	10,197	10,197	10,197	10,197	10,197	10,197	10,197
		Total surface-water inflow	204,920	85,909	234,949	149,511	152,363	155,404	163,843
Outflow									
S7	12419000	Spokane River near Post Falls	217,086	84,489	246,397	149,015	146,215	149,941	165,524
WWTF	ID0022853	City of Coeur d'Alene wastewater treatment facility	150	154	158	154	158	158	155
		Total surface-water outflow	216,936	84,335	246,239	148,861	146,057	149,783	165,369

Flows at the St. Joe River near Chatcolet stream-gaging station were available only for March of water year 2004 through water year 2005. Unavailable flow data (water year 2000 to February 2004) for the Chatcolet stream-gaging station were extrapolated using flows from the St. Maries River near Santa stream-gaging station (S9) and a flow ratio value that was calculated using existing data for the two sites when flows were measured at both sites. The St. Maries near Santa stream-gaging station provided the most complete record for filling in unavailable data for the St. Joe River near Chatcolet stream-gaging station because no flows were measured during water years 2000–2005 at the St. Joe River at St. Maries stream-gaging station (S11), which is the next site upstream from the Chatcolet stream-gaging station. Additionally, an analysis of the combined flows for the St. Joe River at Calder stream-gaging station (S10), and the St. Maries near Santa stream-gaging station, plus effluent to the St. Joe River from the St. Maries wastewater treatment facility located in St. Maries, were suspect and therefore unusable because they were less than the annual flows on the Coeur d'Alene River near Harrison stream-gaging station. Historically, flows into Coeur d'Alene Lake from the St. Joe River are substantially greater than those from the Coeur d'Alene River, as seen in records from water year 2004 (March) to present.

Data from USGS stream-gaging stations on four smaller tributaries were used in the water budget ([table 3](#)); they included Wolf Lodge Creek near Coeur d'Alene (S6), Plummer Creek near Plummer, (S3), Fighting Creek near Rockford Bay (S4), Carlin Creek near Harrison (S5). None of these sites were measured during water years 2000–2005, but they were measured during water years 1991–94. Flows were estimated using flow ratios from the St. Maries River near Santa, and the Coeur d'Alene River near Cataldo stream-gaging stations (S8). Plummer Creek and Fighting Creek data were used with the data from St. Maries River near Santa stream-gaging station. The data for Wolf Lodge Creek near Coeur d'Alene and the Carlin Creek near Harrison stream-gaging stations were used with the Coeur d'Alene River near Cataldo station. A flow ratio was calculated using water years 1991–1992 data and then this flow ratio was used to extrapolate the unavailable flow data for water years 2000–2005.

Inflows for ungaged tributary basins surrounding the lake were calculated using a mean runoff value based on yields from the four smaller tributaries (Plummer, Fighting, Carlin, and Wolf Lodge Creeks), and the residual ungaged tributary area (447 mi²).

Outflows

Outflows from Coeur d'Alene Lake were calculated using data collected from the USGS stream-gaging stations on the Spokane River near Post Falls, Idaho (S7). The gage is at the Post Falls Dam, about 11 mi downstream of the outlet of the Coeur d'Alene Lake, and is used to regulate streamflow in the Spokane River and water levels at Coeur d'Alene Lake. Between December and June, flows in the Spokane River are not restricted at the dam, so generally the outflow at Post Falls Dam is the direct result of inflow (snowmelt, runoff, and precipitation) to the lake. During summer, the dam is used to regulate flows in the Spokane River and to maintain water levels on Coeur d'Alene Lake for recreation (Hortness and Covert, 2005). Mean monthly and mean annual flows at the Spokane River stream-gaging station were calculated using data from water years 2000 to 2005.

Additional data were collected to adjust the flow data for the Spokane River at Post Falls Dam stream-gaging station. The wastewater treatment facility for the city of Coeur d'Alene discharges effluent to the Spokane River near the outlet of the lake. The city of Coeur d'Alene uses groundwater that is pumped from the SVRP aquifer system for public supply, domestic and other uses. Discharges from the wastewater treatment facility are essentially groundwater from the SVRP aquifer that is released to the Spokane River. Wastewater treatment facility discharges were compiled for water years 2000–2005, and subtracted from the mean annual flow at the Spokane River stream-gaging station to adjust for the additional flows to the river that were not associated with the lake (table 3). Similarly, seepage studies on the Spokane River between the outlet and Post Falls Dam indicated that, at least during summer (August), the aquifer gained 291 ft³/s of water from the Spokane River (Hsieh and others, 2007, p. 29). But these data only account for the seepage loss from Spokane River and not losses from Coeur d'Alene Lake. Wyman (1993) estimated that 230 ft³/s of water was lost from Coeur d'Alene Lake and the Spokane River to the SVRP aquifer; therefore, the annual volume of water equivalent to 230 ft³/s (7,250 million ft³, or 167 thousand acre-ft) was used in the budget, however it appears low compared to more recent data by Hsieh and others (2007). More analysis and data collection is needed to more accurately determine the amount of water that the SVRP aquifer gains from Coeur d'Alene Lake and the Spokane River.

Precipitation and Evaporation

Mean monthly precipitation, wind speed, dew point, and air-temperature data from three National Weather Service stations, and miscellaneous water temperature data from

six USGS pelagic monitoring sites were used to calculate the precipitation (positive flux) and evaporation (negative flux) components of the water budget for the lake. The lake is triangulated by three weather stations, Coeur d'Alene 1E (CDA), Plummer 3 WSW (P3), and St. Maries (SM), from which atmospheric data were collected for this study (fig. 1). The Coeur d'Alene station is at the Coeur d'Alene Airport, the Plummer station about 8 mi southwest of the southern edge of the lake near Plummer, Idaho, and the St. Maries station is about 5 mi southeast of the southern tip of the lake in St. Maries, Idaho. Monthly precipitation was calculated using mean monthly precipitation based on the period of record for all three stations (table 4). Annual precipitation was calculated for each year of the water budget using the monthly values of precipitation for that year and the surface area of the lake (50 mi²).

Mean monthly evaporation from the water surface of Coeur d'Alene Lake was calculated using mean monthly air temperature, wind speed, and dew point data from the weather stations and mean monthly water temperature and wind speed data from six USGS pelagic monitoring sites. The data were calculated using methodology described by Allen and Robison (2007) for deep water bodies. This methodology, further explained by Allen and Tasumi (2005), estimates evaporation using the aerodynamic approach and Bowen ratio energy balance gradients derived by the following equations:

$$E = (LE / \lambda) * 0.0864, \quad (2)$$

where

E is evaporation rate, in mm/d,

LE is latent heat flux, in W/m², and,

λ is latent heat of vaporization, in MJ/kg (mean value of 2.48 used in this study).

Latent heat flux is derived as:

$$LE = \lambda \rho_{air} C_E u (q_{satTs} - q_a), \quad (3)$$

where

ρ_{air} is the density of moist air, kg/m³,

C_E is a bulk transfer coefficient for water vapor, dimensionless,

u is wind speed, in m/s,

q_{satTs} is saturated specific humidity at surface temperature, in kg/kg,

q_a is specific humidity at observation height, kg/kg.

Table 4. Summary of mean monthly air temperature, dew point, wind speed, and precipitation data from National Weather Service stations, mean monthly water temperature from U.S. Geological Survey pelagic monitoring stations, 1991–2006, and calculated mean monthly and total mean annual precipitation to and evaporation from Coeur d'Alene Lake, Idaho.

[Locations for sites are shown in [figure 1](#). Methods used from Allen and others (2007). **Precipitation (in.)** based on period of record for stations Coeur d'Alene 1E (CDA), Plummer 3 WSW (P3), and St. Maries (SM). **Abbreviations:** acre-ft, acre-foot; °C, degrees Celsius; CDA, weather station at Coeur d'Alene 1E; in., inch; in/month, inch per month; kg/m³, kilogram per cubic meter; kg_{vapor}/kg_{air}, kilogram of vapor per kilogram of air; m/s, meter per second; ρ_{air} , density of moist air; q_{saTs} , saturated specific humidity at surface temperature (T_s); q_a , specific humidity at observation height; $e_{surface}$, water surface vapor pressure; e_{air} , air vapor pressure; LE, latent heat flux; W/m², watt per square meter; E, evaporation rate; USGS, U.S. Geological Survey; na, not applicable]

Month	Air temperature (°C)	CDA weather station		Mean precipitation (in.)	USGS pelagic stations		Coeur d'Alene Lake							
		Dew point (°C)	Wind speed (m/s)		Water temperature (°C)	Precipitation (acre-ft)	Evaporation (acre-ft)	ρ_{air} (kg/m ³)	q_{saTs} (kg _{vapor} /kg _{air})	q_a (kg _{vapor} /kg _{air})	e_{sat} (kPa)	e_{air} (kPa)	LE (W/m ²)	E (in/month)
January	-1.6	-7.8	3.5	3.7	1.8	9,850	3,850	1.2	0.0044	0.0023	0.67	0.34	34	1.4
February	.73	-3.9	3.4	2.9	1.8	7,720	2,940	1.2	.0049	.0030	.74	.46	28	1.1
March	3.8	-2.8	3.7	2.4	1.6	6,390	3,250	1.2	.0051	.0033	.76	.50	28	1.2
April	7.7	0	3.5	2.0	3.0	5,320	2,950	1.2	.0058	.0041	.88	.61	27	1.1
May	12	4.4	3.4	2.3	7.2	6,120	2,500	1.1	.0071	.0056	1.1	.84	22	.94
June	15	7.8	3.2	1.9	12.8	5,270	3,390	1.1	.0094	.0071	1.4	1.1	31	1.3
July	20	8.9	3.0	.8	17.2	2,080	7,500	1.1	.013	.0076	1.9	1.1	65	2.8
August	19	8.3	3.0	1.0	17.3	2,660	9,150	1.1	.014	.0073	2.1	1.1	80	3.4
September	15	5.6	3.0	1.2	14.3	3,190	7,360	1.1	.011	.0061	1.7	.91	66	2.8
October	8.4	3.3	3.0	2.3	11.9	6,120	6,140	1.2	.0094	.0052	1.4	.77	54	2.3
November	2.6	0	3.4	3.7	3.4	9,850	3,900	1.2	.0064	.0041	.97	.61	35	1.5
December	-1.1	-3.9	3.4	4.0	3.4	10,600	3,930	1.2	.0053	.0030	.80	.46	35	1.5
Total	na	na	na	na	na	75,200	56,860	na	na	na	na	na	na	21

The bulk transfer coefficient for water vapor (C_E), was estimated as 0.0015 (Richard G. Allen, University of Idaho, written commun., 2007). Latent heat flux was calculated using the mean monthly air temperatures, wind speeds, dew points, and water-surface temperatures shown in [table 4](#). Density of moist air in equation 3 is calculated as:

$$\rho_{air} = 3.486P / \left(\frac{T + 273.15}{(1 - 0.378e_{air}/P)} \right), \quad (4)$$

where

P is atmospheric pressure, or 93.76 kPa at an elevation of 658 m,

T is air temperature, in °C, and

e_{air} is vapor pressure, in kPa.

Specific humidity, (q in equation 3), is calculated using vapor pressure (e) from Allen and Robison (2007):

$$q = \frac{0.622e}{P - 0.378e}, \quad (5)$$

where

q is specific humidity, in kg/kg, and

e is vapor pressure, in kPa.

The vapor pressure at water surface was calculated as saturation pressure at water surface temperature. Air vapor pressure, e_{air} , is the air vapor pressure used in equation 4 to calculate q_a . The functions used from Allen and Robison (2007) for vapor pressure were:

$$e_{surface} = 0.6108 \exp \left[\frac{17.27T_s}{T_s + 237.3} \right], \quad (6)$$

$$e_{air} = 0.6108 \exp \left[\frac{17.27 T_{dew}}{T_{dew} + 237.3} \right], \quad (7)$$

where

T_s is mean water surface temperature, °C, and

T_{dew} is mean dewpoint temperature, °C.

Mean monthly air temperature and precipitation data collected from all three weather stations between 1996 and 2006 were used to calculate mean monthly and annual values of evaporation. The Plummer 3 WSW (P3) and the St. Maries (SM) stations lacked dew point and wind speed data; therefore, dew point and wind speed data for the same period were used from Coeur d'Alene 1E (CDA) station. Unavailable temperature data were replaced with the mean monthly values from the 30-year period from 1971 to 2000. Additionally, water temperature and wind speed data were collected intermittently at the USGS pelagic monitoring sites between 1989 and 2006, mostly between April and July (Deb Parlman and Molly Wood, U.S. Geological Survey, written commun., 2007). Water temperatures collected at 1-m depths were used to compute mean monthly water temperatures. Insufficient data were available during September; therefore, the average of August and October was used to calculate the September mean monthly water temperature. Mean monthly water temperatures ranged from a minimum of 1.6°C in March to a maximum of 17.3°C in August (table 4).

Lake Storage and Withdrawals

The USGS station (Coeur d'Alene Lake at Coeur d'Alene, L7) is just southwest of the city of Coeur d'Alene. In operation since 1903, this station provides the lake stage data that is converted to storage in the lake above the 2,120 ft elevation. This study used the same capacity conversion table that is currently used to report the storage in the annual Idaho water data reports (<http://wdr.water.usgs.gov/>) (Tom Brennan, U.S. Geological Survey, written commun., 2007). Changes in storage were calculated using the mean monthly storage during the study period, and summarized to annual net changes for each water year (table 5). No data were available for January 2004; therefore, the unavailable value was replaced with the mean monthly January value.

Releases from Coeur d'Alene Lake are regulated at Post Falls Dam and, during summer, flows are maintained to accommodate sufficient lake levels when recreational use of the lake is at its annual peak. Using mean monthly changes in storage for the period of record, the greatest monthly gains in storage occurred between March and April when spring runoff

occurs, with an average net gain of more than 2,000 million ft³ (49,700 acre-ft). The largest average monthly loss from storage was between September and October, with an average net loss of almost 1,800 million ft³ (41,000 acre-ft).

Coeur d'Alene Lake is a source of water for domestic uses, including fire protection, landscape irrigation, some livestock, and aesthetics. The lake also serves municipal and other irrigation (golf course), commercial, and industrial uses. Twenty small municipal or homeowner associations hold water rights for surface water from Coeur d'Alene Lake (Idaho Department of Water Resources, written commun., 2007). The city of Coeur d'Alene holds a surface-water right but did not use any water from Coeur d'Alene Lake during water years 2000-2005 (Jim Markley, Coeur d'Alene City Water Department, Superintendent, verbal communication, 2008). The IDWR water rights database contains over 320 water-rights for Coeur d'Alene Lake water, and most of those rights are filed by individual homeowners and allocated for domestic uses, for which no measured data exist. Water rights data were used to estimate monthly withdrawals if reported data were lacking; few of the municipal or homeowner associations measure withdrawals. However, three associations reported annual data that were used in this study: Harbor View Estates, Black Rock, and Cottowood Point.

Using the water-rights database and assuming that all the homeowners used their full allocation of water during the year, a mean annual withdrawal from Coeur d'Alene Lake was estimated at about 1,270 million ft³ (29,100 acre-ft) (table 6). However, not all withdrawals are consumptively used; in fact, only a small part of the withdrawals are lost to evapotranspiration or exported from the basin. Most withdrawals are returned to the lake through groundwater recharge from irrigation, runoff, or septic system infiltration. A consumptive-use coefficient of 15 percent (Shaffer, 2008) was used to estimate that part of total withdrawals that was consumptively lost, resulting in an estimated net loss from Coeur d'Alene Lake of about 190 million ft³ annually (4,368 acre-ft).

Another approach to estimating withdrawals for all domestic water uses is to use per capita use rates based on a 2005 USGS survey of cities in Kootenai County. The survey queried Coeur d'Alene and St. Maries water supply facilities for total public-supply withdrawals and customer information. A per capita use rate of 330 gallons per capita per day (GPCD) was calculated for the city of Coeur d'Alene. The GPCD rate for Coeur d'Alene was used to estimate withdrawals for all domestic records with a surface-water right from Coeur d'Alene Lake, assuming that a single record will serve one household and that an average of 2.6 persons occupy each household. About 300 households had water rights from the lake, which resulted in a total annual estimate for domestic

12 Water Budgets for Coeur d'Alene Lake, Idaho, Water Years 2000-2005

withdrawals of 12.6 million ft³ (290 acre-ft). The per capita use rate estimate is clearly much less than the water-right estimate; therefore, to avoid potentially underestimating withdrawals, consumptive use was calculated on the withdrawals based on the water-right estimate and used in the annual water budgets.

Groundwater withdrawals for domestic wells within a 1,000 ft buffer around Coeur d'Alene Lake were assessed using IDWR water-rights file records and the 330 GPCD use rate. A conservative count of 520 wells was established by eliminating duplicate records from analysis. The actual

number of wells surrounding the lake may be greater. An annual groundwater withdrawal estimate of 21.8 million ft³ (500 acre-ft) was calculated from groundwater sources within 1,000 ft of the shoreline. Using the 15 percent consumptive-use coefficient, the total annual net loss from nearshore groundwater withdrawals was estimated at 3.2 million ft³ (75 acre-ft). The annual net loss from estimated groundwater withdrawals was combined with the estimated net loss from surface-water withdrawals for a total consumptive use of 265 million ft³ (6,097 acre-ft).

Table 5. Change in storage and summary of mean monthly storage, Coeur d'Alene Lake, Idaho, water years 2000–2005.

[Abbreviations: ft, foot; ft³, cubic foot; acre-ft, acre-foot; –, not applicable]

Water year	January	February	March	April	May	June	July	August	September	October	November	December	Water year change (million ft ³)	Water year change (acre-ft)
Change in storage (above 2,100 ft elevation) using mean monthly stage, converted to acre-ft, and subtracted from previous month														
1999	–	–	–	–	–	–	–	–	–	-60,220	-22,310	10,630	–	–
2000	-60,540	30,810	42,250	151,020	-58,400	-23,370	7,050	0	-11,160	-60,380	-67,190	-45,190	251	5,760
2001	-22,850	2,160	31,760	71,240	98,790	470	5,210	-960	-18,380	-52,220	-27,180	-25,440	-231	-5,320
2002	3,040	-22,070	35,430	3,310	171,740	-6,630	-66,320	6,160	-19,820	-64,020	-47,060	-18,290	0	0
2003	-11,070	75,860	-12,890	36,610	-19,800	77,610	950	480	-20,980	-45,270	-61,320	-31,250	-113	-2,600
2004	5,940	-5,130	46,570	51,580	11,450	47,930	-1,420	2,860	-6,150	-64,540	-31,080	21,770	688	15,790
2005	-45,560	-4,050	-25,040	102,510	36,320	13,900	1,920	-2,390	-24,230				-892	-20,470
Average monthly storage for period of study (acre-ft)	-21,840	12,930	19,680	69,378	40,017	18,318	-8,768	1,025	-16,787	-57,775	-42,690	-14,628		-1,140
Average monthly storage for period of study, million ft ³	-951	563	857	3,022	1,743	798	-382	45	-731	-2,517	-1,860	-637	-49	–
Net mean monthly change (as calculated from previous month), for period of study	–	1,515	294	2,165	-1,279	-945	-1,180	427	-776	-1,785	657	1,222	–	–
Summary of mean monthly storage, in acre-ft, for Coeur d'Alene Lake (above 2,100 ft elevation) using mean monthly stage, converted to acre-ft													Water year average storage (acre-ft)	
1999	–	–	–	–	–	–	–	–	215,840	155,620	133,310	143,940	–	
2000	83,400	114,210	156,460	307,480	249,080	225,710	232,760	232,760	221,600	161,220	94,030	48,840	188,028	
2001	25,990	28,150	59,910	131,150	229,940	230,410	235,620	234,660	216,280	164,060	136,880	111,440	141,350	
2002	114,480	92,410	127,840	131,150	302,890	296,260	229,940	236,100	216,280	152,260	105,200	86,910	179,978	
2003	75,840	151,700	138,810	175,420	155,620	233,230	234,180	234,660	213,680	168,410	107,090	75,840	163,126	
2004	81,780	76,650	123,220	174,800	186,250	234,180	232,760	235,620	229,470	164,930	133,850	155,620	160,506	
2005	110,060	106,010	80,970	183,480	219,800	233,700	235,620	233,230	209,000	158,420	115,830	58,560	172,189	
Average (acre-ft)	81,925	94,855	114,535	183,913	223,930	242,248	233,480	234,505	217,718	161,550	115,480	89,535	167,529	

Table 6. Summary of monthly estimated surface-water withdrawals, and consumptive use, for domestic and municipal water uses, Coeur d'Alene Lake, Idaho.

[All values are in million cubic feet. Estimates of consumptive use for surface-water withdrawals only. Values may not sum to totals because of independent rounding]

	January	February	March	April	May	June	July	August	September	October	November	December	Total annual
Total municipal withdrawals	31.3	28.3	31.3	30.3	31.3	30.3	31.3	31.3	30.3	31.3	30.3	31.3	369
Total domestic withdrawals, including fire protection and landscape irrigation	55.5	50.3	79.4	80.5	83.8	81.6	84.4	84.4	81.6	84.9	76.8	55.7	897
Total withdrawals, all uses	86.8	78.6	110.4	110.8	115.1	111.9	115.7	115.7	111.9	115.2	107.1	87.0	1,266
Estimated consumptive use (15 percent)	13	11.8	16.6	16.6	17.2	16.8	17.3	17.3	16.8	17.3	16.1	13.1	190

Uncertainties of Water Budget Components

The development of any water budget involves uncertainty and associated errors. The water-budget residual value is the mathematical difference between all inflow and outflow components, and includes errors associated with those components, as well as unquantified water-budget components such as groundwater fluxes between the lake and bank storage. Uncertainties are expressed as error percentages for components that were measured or estimated, and these uncertainties may refer back to error percentages and methods previously described for Coeur d'Alene Lake (Woods and Beckwith, 1997) and elsewhere (Winter, 1981; Brown, 1987).

Surface-water inflows for gaged tributaries represent most of the total contributing drainage basin of Coeur d'Alene Lake (92 percent); most USGS streamflow records were rated as good, but a few were rated as fair. Records that are rated as excellent, good, or fair are considered within 5, 10, and 15 percent, respectively, of the actual daily streamflow 95 percent of the time (Brennan and others, 2006). A known deficiency exists in the accuracy of the historical flows for the St. Joe River near Chatcolet (S2). Data for spring-time runoff may be underreported (low), possibly by as much as 25 percent, because some flows bypass the site during high-flow events (Molly Wood, U.S. Geological Survey, oral commun., 2008). Therefore, high flows recorded at the St. Joe River near Chatcolet site may be lower than actual flows. Considering all of the sites and reported ratings for each site and water year, an overall rating of fair (15 percent) was assigned to mean annual inflows for all gaged tributaries. Ungaged surface-water inflows were calculated using methods comparable to those used by Woods and Beckwith (1997),

who constructed a water budget for water years 1991 and 1992 and assigned a 25-percent error for the ungaged component of that budget. The same percentage of error was adopted for this study.

Surface-water outflows were calculated using the stream-gaging station on the Spokane River at Post Falls Dam (S7), which was rated as good for water years 2000–2005; therefore, the surface-water outflow component of the water budget was assigned a 10 percent error estimate. Similarly, data at the Coeur d'Alene Lake station (L7), which is used to determine changes in lake storage above 2,120 ft elevation, were reported as good for water years 2000–2005; therefore, a 10 percent error was assigned to the net change in lake storage component of the water budgets.

The precipitation component of the water budgets is the quantity of water that fell directly on the lake surface. The NWS weather stations are close to the lake. Errors associated with precipitation data that are averaged over long periods are smaller than those averaged over short periods (Winter, 1981). Precipitation data (table 1) for the mean annual water budget were calculated using precipitation data for the period of record for all weather stations and the total surface area of the lake. A 15 percent error is assigned for the precipitation component of the water budget. Evaporation estimates derived from an energy budget method for longer periods (annual basis) are more accurate than other methods for shorter periods (Winter, 1981). For this study water temperature and wind speed data were available from USGS pelagic stations on Coeur d'Alene Lake (L1 – L6). Also, the evaporation calculations were based on mean monthly, rather than mean daily, time steps as outlined in Allen and Tasumi (2005). Therefore, the evaporation component of the water budgets was assigned a 10 percent error.

The water-use withdrawals and subsequent consumptive use estimates have the least amount of quantifiable information. Little research and data are available for the consumptive use component, and consumptive use estimates are based solely on total withdrawal estimates for which few measured data are available. A 25 percent error was assigned to the consumptive use estimate. Similarly, the seepage losses from Coeur d'Alene Lake and the Spokane River to the SVRP aquifer were difficult to ascertain from historical records. A 15 percent error was assigned to the seepage loss estimates.

The residual value incorporates all of the water-budget errors and unquantified values for aspects of the hydrologic cycle not included in this study. For the study period, the residual value was always negative, and the percentages of the residual value as compared to total inflow or total outflow were within the range of errors for many of the budget components. The standard deviation of the residual value error is equal to the square root of the sum of the standard deviation of individual components' errors, squared, expressed as:

$$OE = \sqrt{[(E1)^2 + (E2)^2 + \dots (En)^2]}, \quad (8)$$

where

OE is total standard deviation error associated with the water budget, in million cubic feet; and

En is the standard deviation error associated with each budget component.

The uncertainty in the water budget components, as expressed as the total standard deviation error for the budget components, was 46,400 million ft³, compared to the net residual value term of -8,310 million ft³. Uncertainty in the water budget components is five times as large as the net residual value.

Summary and Conclusions

The U.S. Geological Survey, in cooperation with the Idaho Department of Water Resources, calculated annual water budgets for Coeur d'Alene Lake and a mean annual budget for study period water years 2000–2005. The calculation and associated uncertainty of the following major water-budget components were included: (1) inflows, including precipitation

to the lake surface and all gaged and ungaged tributary surface-water inflows; (2) outflows, including evaporation from the lake surface, consumptive use of withdrawals from the lake and wells near the lake, and the flow of the Spokane River, which is the main outlet of the lake; and (3) changes in lake storage, seepage from Coeur d'Alene Lake and the Spokane River to the Spokane Valley-Rathdrum Prairie (SVRP) aquifer system, and a residual value.

Mean annual inflow to Coeur d'Alene Lake for the study period, including precipitation, was about 167,110 million cubic feet (3,836 thousand acre-feet). Mean annual outflow for the study period, including evaporation, was about 167,850 million cubic feet (3,853 thousand acre-feet). Losses from Coeur d'Alene Lake and the Spokane River to the SVRP aquifer was 7,250 million cubic feet (167,000 acre-feet). Mean annual precipitation into Coeur d'Alene Lake was 3,267 million cubic feet (75,000 acre-feet), which exceeded mean annual evaporation of 2,483 million cubic feet (57,000 acre-feet). Consumptive use for surface-water and groundwater withdrawals was 265 million cubic feet (6,100 acre-feet). Change in storage resulted in a net loss of about 49 million cubic feet (1,100 acre-feet). The residual value for water years 2000–2005 was about -8,310 million cubic feet (191,000 acre-feet).

Inflow from gaged tributaries was 92 percent of the mean annual total inflows, ungaged inflow was 6 percent, and mean annual precipitation was about 2 percent. The Spokane River outflow was 94 percent of the mean annual total outflows, evaporation from the lake surface about 1.5 percent, losses to the SVRP aquifer from Coeur d'Alene Lake and the Spokane River 4 percent, consumptive use 0.2 percent, and net change in storage 0.03 percent. The mean annual residual value was 5 percent of the total inflows and nearly 5 percent of the total outflows. A negative residual value was calculated each year, but the residual values are within an acceptable margin of error for the budget components that are the largest percentage of total inflows and outflows.

Total inflow and outflow volumes, adjusted for changes in lake storage, losses to the SVRP aquifer, and consumptive use resulted in a negative (net loss) residual value for each water year. The mean annual residual value for the six water years was -8,310 million cubic feet (190,000 acre-feet). The residual value is assumed to consist of unqualified water-budget components, such as groundwater fluxes around the lake, and uncertainties associated with all other measured and estimated water-budget components.

References Cited

- Allen, R.G., and Robison, C.W., 2007, Evapotranspiration and consumptive irrigation water requirements for Idaho: Moscow, University of Idaho Research and Extension Center at Kimberly, Research Technical Completion Report, 246 p., accessed May 22, 2009, at http://www.kimberly.uidaho.edu/ETIdaho/ETIdaho_Report_April_2007.pdf
- Allen, R.G., and Tasumi, M., 2005, Evaporation from American Falls Reservoir in Idaho via a combination of Bowen Ratio and Eddy Covariance: Proceedings of the 2005 Environmental and Water Resources Institute, American Society of Civil Engineers, May 15-19, 2005, Anchorage, Alaska, accessed May 22, 2009, at http://www.kimberly.uidaho.edu/water/papers/Allen_Tasumi_Am_Falls_final_d.pdf
- Beckwith, M.A., Woods, P.F., and Berenbrock, Charles, 1997, Trace-element concentrations and transport in the Coeur d'Alene River, Idaho, water years 1993–94: U.S. Geological Survey Open-File Report 97-398, 7 p.
- Brennan, T.S., Lehmann, A.K., and O'Dell, I., 2006, Water Resources Data—Idaho, 2005: U.S. Geological Survey Water-Data Report ID-05-1, 469 p.
- Brown, R.G., 1987, Errors in estimating ground-water components of hydrologic and phosphorus budgets of lakes, in Subitzky, Seymour, ed., Selected papers in the hydrologic sciences: U.S. Geological Survey Water-Supply Paper 2310-D, p. 53-64.
- Hortness, J.E., and Covert, J.J., 2005, Streamflow trends in the Spokane River and tributaries, Spokane Valley/Rathdrum Prairie, Idaho and Washington: U.S. Geological Survey Scientific Investigations Report 2005-5005, 17 p.
- Hsieh, P.A., Barber, M.E., Contor, B.A., Hossain, Md.A., Johnson, G.S., Jones, J.L., and Wylie, A.H., 2007, Ground-water flow model for the Spokane Valley-Rathdrum Prairie aquifer, Spokane County, Washington, and Bonner and Kootenai Counties, Idaho: U.S. Geological Survey Scientific Investigations Report 2007-5044, 78 p., accessed May 22, 2009, at <http://pubs.usgs.gov/sir/2007/5044/>
- Molnau, Myron, 2000, Precipitation for Idaho—Mean annual (1961–90): Idaho State Climate Services, accessed June 16, 2009, at <http://inside.uidaho.edu/asp/metadata/metadata.aspx?ResourceID=73&XSL=FGDCClassic.xsl>
- Rantz, S.E., and others, 1982, Measurement and computation of streamflow: U.S. Geological Survey Water-Supply Paper 2175, 2 v., 631 p.
- Shaffer, K.H., 2008, Consumptive water use in the Great Lakes Basin: U.S. Geological Survey Fact Sheet 2008-3032, 6 p., accessed May 22, 2009, at <http://pubs.usgs.gov/fs/2008/3032/>
- U.S. Census Bureau, 2008, State and county quickfacts, Kootenai County: U.S. Census Bureau, accessed May 22, 2009, at <http://quickfacts.census.gov/qfd/states/16/16055.html>
- Western Regional Climate Center, 2008, Idaho climate summaries: Western Regional Climate Center, accessed May 22, 2009, at <http://www.wrcc.dri.edu/summary/climsmid.html>
- Winter, T.C., 1981, Uncertainties in estimating the water balance of lakes: Water Resources Bulletin, v. 17, no. 1, p. 82-115.
- Wood, M.S., and Beckwith, M.A., 2008, Coeur d'Alene Lake, Idaho—Insights gained from limnological studies of 1991–92 and 2004–06: U.S. Geological Survey Scientific Investigations Report 2008-5168, 40 p., accessed May 22, 2009, at <http://pubs.usgs.gov/sir/2008/5168/>
- Woods, P.F., and Beckwith, M.A., 1997, Nutrient and trace-element enrichment of Coeur d'Alene Lake, Idaho: U.S. Geological Survey Water-Supply Paper 2485, 93 p.
- Wyman, S.A., 1993, The potential for heavy metal migration from sediments of Lake Coeur d'Alene into the Rathdrum Prairie aquifer, Kootenai County, Idaho: University of Idaho Department of Geology and Geological Engineering Research Technical Completion Report, November 1993, 141 p.

This page intentionally left blank.

Publishing support provided by the U.S. Geological Survey
Publishing Network, Tacoma Publishing Service Center

For more information concerning the research in this report, contact the

Director, Idaho Water Science Center
U.S. Geological Survey
230 Collins Road
Boise, Idaho 83702
<http://id.water.usgs.gov>

